COSEE Evidence of Success
A Review

Introduction

In 2002, the National Science Foundation (NSF) Division of Ocean Sciences (OCE) established COSEE (Centers for Ocean Sciences Education Excellence)—a Network of coordinated Centers to facilitate collaborations and communications between ocean science researchers and educators in formal and informal education settings. Since then, each Center has developed a broad range of services, activities, and products to improve ocean sciences education by engaging and partnering with the ocean sciences research community.

Centers and Center evaluators over the past nine years have collected evidence indicating that COSEE has successfully served NSF, the ocean sciences research community, educators, and the public through three channels:

1) Understanding scientists' needs and issues related to the fulfillment of broader impacts for research proposals
2) Developing scientists' communication skills, pedagogy, and understanding of audience needs, education culture and educators' needs so that they can more effectively implement broader impacts projects
3) Connecting ocean scientists with educators and public audiences in ways that have transformed ocean sciences education

This document reviews and summarizes Center evidence compiled on the types and efficacy of services to the ocean sciences research community that COSEE has been providing to improve the quality, availability and impact of ocean sciences education in formal and informal education settings.

Channel I: Understanding Needs Related to Supporting Broader Impacts

COSEE was established in 2001 by the OCE, in part, to assist ocean sciences researchers with NSF's Broader Impacts Criterion II. The newly funded Centers recognized that to engage scientists in endeavors that they valued most and that provided the greatest impact relative to investment, staff needed to know more about ocean scientists' needs, broader impacts activities, and barriers. Centers pursued that knowledge through literature reviews, surveys and interviews.

Literature Reviews

Several Centers reviewed the current research literature. The most comprehensive was conducted by COSEE Great Lakes (GL) and published in Kim & Fortner (2008). In their summary, they noted that scientists become involved in K-12 education/outreach for a variety of reasons. Funding agencies had begun to enforce their grantees' participation and some universities required community service. But scientists also engaged on their own—in their children's classrooms or in aid to local organizations. Several published studies described barriers to scientists' involvement in education/outreach, primarily lack of time and funding, lack of information about opportunities, and the absence of professional rewards. In addition, strong collaboration and partnerships between scientists and educators required a careful negotiation of the boundaries between distinct academic cultures—science and education. Rewards for scientists, which included improved teaching skills, learning about pedagogy, and disseminating science to broader audiences, tend not to override those barriers.

In addition to education/outreach, reaching underserved audiences is another broader impacts category and a substantial barrier for some scientists. The COSEE Diversity Working Group (a multi-Center collaboration) worked to address this need by conducting and annotating a targeted literature review with an overview of resources (organizations, policy documents, research studies, intervention studies, etc.) for the COSEE Network.

Charrettes

A number of Centers—in particular, Mid-Atlantic (MA), New England (NE), and South East (SE)—held charrettes or workshops with scientists, educators, and other stakeholders to identify their needs and shape critical messages for public audiences.

COSEE NE's scientists expressed the desire to understand the needs of individual teachers and students with whom they would work, as well as the interests and concerns of the broader science education community. They also wanted to know how scientists effectively work with teachers and students and how to get involved by locating and making connections with interested educators. COSEE NE found that the networking meeting was useful for participants and led to meaningful exchanges. At a similar meeting held by COSEE MA, scientists wanted to get started immediately with the educators in attendance.

Both NE and MA found that meetings, by themselves, could not create nor sustain scientist-educator partnerships that would contribute to the development of new programs or exhibits. Participants' time and access to resources and continuing support were required for them to take the next steps.

COSEE SE learned from early planning meetings that they would need to provide extensive resources in person and on the Web, as well as partner with existing programs focused on serving diverse audiences. Building community was a required element of communicating with the broader audiences that scientists wished to reach.

Surveys and Interviews

In addition to literature reviews and charrettes, several Centers, including California (CA), GL, MA continuing as Networked Ocean World (NOW), NE and SE conducted scientist surveys, and for some, selected follow-up interviews, to collect needs assessment data from their scientist communities and to establish baselines of practice. Centers collected data to understand problems and issues before implementing solutions and to track changes over time.

Major findings from these Center surveys mirrored the research literature. Surveys found that scientists perceived the major barriers to their involvement in education/outreach and other broader impacts to be funding, time, and professional rewards. (This was also true of educators surveyed by COSEE GL.)

> *The problem here is that people who are already very busy are being pressed to do additional work that they mostly have no experience with, and not being told that they can stop doing something else... What I could really use are relatively easy ways to plug into existing projects... K-12 educators who are interested in collaborating, groups developing teaching materials, already active public outreach avenues... so that it is as easy as possible to do something that seems useful.*
>
> ~COSEE NOW Scientist Survey Response

> *I have been involved in a great deal of public outreach and taken science literacy and teaching courses. I think the greatest assistance would come from recognition in the value of this work at my institution and others. More information about outreach funding would also be very helpful.* ~COSEE NOW Scientist Survey Response

In addition, scientists who were interested often didn't know how to get involved.

> *I am EXTREMELY interested in outreach, but consider myself horribly uninformed on the myriad opportunities that must exist, and am a bit frustrated that I haven't been able to do more.* ~COSEE CA Scientist Survey Response

Scientists' professional training and their lack of knowledge about professional education practice probably contributed significantly to the barriers they described. Survey data analysis by COSEE GL found that several predictor variables accounted for the majority of variance in explaining scientists' experiences in collaborating with teachers: familiarity with terms in education, professional training (educational competencies and collaborative cultures), and age. Results also showed that most scientists had little opportunity to obtain knowledge about professional education during their professional science training. COSEE NOW survey results showed that the vast majority of scientists gained their skills in education/outreach by teaching or by observing others teach, and that most turned to other scientists when they needed advice or help with education/outreach.

The early data gathering also provided details about specific groups within the science research community. COSEE SE sponsored a study to establish a benchmark for the diversity of the ocean sciences workforce in the Southeast region of the U.S. Their ultimate goal is for the workforce for ocean sciences to reflect the demographics of the U.S. Analyses of the baseline survey data of the ocean sciences workforce and graduate students showed that the current demographic did not reflect the demographic diversity of the Southeast region or the U.S.

Additional surveys found differences in dedication to broader impacts among established scientists, early career scientists and graduate students. COSEE NOW surveys have found that early career scientists, including graduate students, are more involved in and supportive of education/outreach activities than their more established mentors and colleagues. However, like their colleagues, they expressed the need for more support and training.

Two Centers have conducted a series of scientists' surveys and have found changes over time. COSEE CA compared survey and interview data from scientists in 2005 and 2007, finding that respondents in 2007 were spending more time doing education/outreach, perceived fewer barriers to and more institutional support for conducting education/outreach, and were more familiar with COSEE, in particular COSEE CA. However, they still viewed institutional appreciation and professional incentives as efforts that would facilitate more education/outreach.

> *...Having been a researcher for a while and seeing that environment and [its] unsophisticated, unfriendly and unreceptive [nature] to real movement in outreach [in the past], it's been rewarding to be a part of the effort to move that forward. I think there's really been a cultural change. More researchers are interested in*

> *getting involved. [There is a] global interest and a realization of the importance to their work in both the long term and maybe even the short term.*
>
> ~COSEE CA Interview Response

Graduate students surveyed by COSEE CA in 2007 demonstrated a significant difference in attitudes and ideas about education/outreach compared to those from 2005. Statistically significant increases regarding the importance of getting involved in education/outreach and the perception of institutional support and professional benefits of such activities all suggested a shift in how the graduate students perceived education/outreach activities and their role in doing such. Changes in students' attitudes about education/outreach were particularly impressive, as these are the scientists and faculty of the near future, who may continue such efforts and pass on their increased appreciation of its importance to their students.

Results from the COSEE NOW annual surveys of ocean scientists (through ORION and ASLO), have shown increases in scientists' involvement in education/outreach from 2004 to 2010. The vast majority of scientists were consistently supportive of education/outreach efforts specifically, and broader impacts initiatives in general. Most engaged in such activities, whether they were required to or not, and acknowledged the benefits to society and themselves.

Again, scientists continued to say that they wanted help. They needed more funding and staffing and greater professional and institutional recognition (funding, tenure, training) for their education/outreach work. When COSEE NOW asked for specifics regarding assistance, ocean scientists stated that they wanted help with research dissemination to broader audiences, examples of successful quality education/outreach projects, creative ideas, and links or access to ongoing and planned education/outreach projects.

Broader Impacts Support

Since the start of COSEE, all Centers have assisted scientists with developing broader impacts statements and projects as part of their research proposals. This has helped to mitigate some of the issues of time and support expressed by scientists. Results have varied greatly depending on the size of individual Centers and their scientific community. One of the largest and longest running Centers—COSEE CA—has facilitated the inclusion of education/outreach components in more than 130 research proposals directly benefiting more than 200 scientists from 18 California institutions. One of the newer and smaller Centers—COSEE Pacific Partnerships (PP)—has assisted with the development of 14 proposals, of which seven have received notice and three were funded.

Tangible assistance in the form of modest financial support, logistical support, volunteers or paid staff, and helpful advice was a small but visible portion of the services Centers provided to the ocean sciences research community. This assistance was a boost to new ideas or expansion of existing activities. COSEE OLC supported the launch of Sound Citizen, a participatory-based *Citizen Science* effort providing logistical support, volunteer support, and venues for communicating about efforts to carefully measure local water contaminants. Another example from COSEE OLC is the support given to Dr. Danny Greenbaum (University of Washington scientist) in being selected for the Science Advocate Award with its $5000 cash award.

However, the impact of COSEE with regards to broader impacts has been vast overall. On the

COSEE 2011 Network Scientist Engagement Survey (n ≈ 400), when asked about assistance with broader impacts as defined by NSF, 70% of scientists reported that their involvement in "broader impacts" had increased as a result of COSEE. [See the Scientist Engagement Survey documents in this Decadal Review package.]

> *The primary benefit is to be part of a Network of organized outreach and education efforts rather than my previous practice of trying to come up with a good education and outreach component solo. COSEE has helped me identify gaps that need filling the most urgently.* ~COSEE Scientist Engagement Survey Response

A large majority of scientists said that COSEE had positively impacted areas such as opportunities to engage in education/outreach (80%), knowledge of science education practices (74%) and contributions to ocean sciences education in formal or informal venues (73%).

> *Most importantly, I'm exposed to new ideas and tools that enable me to broaden the impact of my research. When presenting the results of my work, I now always think of the wider audience. Also, I am better prepared to teach about ocean science in ways that can accommodate for different styles of learning. Finally, I benefited by interacting with formal and informal educators whose expertise was previously unavailable to me* ~COSEE Scientist Engagement Survey Response

Many scientists reported that COSEE has had a positive impact on their opportunities to present their research to non-scientific audiences (63%), their ability to develop high-quality broader impacts proposals (51%), and to reach out to underrepresented audiences/groups (50%).

> *Main benefits have been a better connection to a wider range of science educators as well as information on research projects and scientific information that are relevant to our laboratory's science missions, which we may not have had as ready access to without COSEE. In this coming year, I'm looking forward to partnering formally with COSEE on a teacher science education class to be hosted at our lab. Partnering with COSEE to offer intensive coastal marine science training for both teachers and underserved populations, provides an effective way to leverage COSEE's education expertise with our facility's capabilities and location.*
> ~COSEE Scientist Engagement Survey Response

Twenty-three percent said that COSEE has positively impacted their success in securing funding and, for 15%, COSEE has had a positive impact in publishing ocean sciences education articles.

When COSEE NOW asked ASLO scientists who had been engaged with COSEE if their views or relationship with education/outreach had changed as a result, they had. Of the responses offered, 56% indicated they had a greater respect for those doing education/outreach, 44% viewed education/outreach more positively, 42% viewed broader impact initiatives more positively and the same percentage considered audiences' interests more when they taught.

> *I better understand how to "frame" my research topic (which is quite narrow in some respects) so that it fits into broader themes of scientific importance to all citizens.*
> ~COSEE Scientist Engagement Survey Response

Needs assessment information that COSEE has gathered has informed Centers' work with scientists to improve education/outreach capacity and facilitate scientist-educator interactions. The next sections of this document present evidence of COSEE's work in those two areas.

Channel II: Supporting Scientists with Education/Outreach

COSEE has emerged as the foremost service platform for ocean scientists seeking support for fulfilling broader impacts requirements aimed at informing, engaging, and inspiring public audiences, as well as motivating them to learn more about ocean sciences. Initially, support services were initiated within individual Centers, but in recent years several programs and products have been disseminated throughout the Network, establishing a legacy for COSEE.

COSEE's support to scientists can be categorized into these sectors: 1) professional development in support of engaging in education/outreach; 2) tools for use with, or support for, education/ outreach; 3) information, consultation, and advice for expanding broader impacts and engaging in education/outreach; and 4) establishing collaborations and productive partnerships in furtherance of an education/outreach mandate. Each of these services has taken multiple forms supporting one or more of the following types of activities: grant writing, education/ outreach activities, broader impacts requirements development and implementation, cultivating collaborations between and among individuals and organizations, working with teachers (K-16), working with the public, and scientists' professional development focused around teaching and learning.

Professional Development for Scientists in Support of Education/Outreach

Centers have provided professional development and training for scientists seeking to improve their education/outreach efforts. These programs range from short interventions, such as workshops and trainings, to longer-term interventions such as academic coursework. Several professional development initiatives have been disseminated throughout the Network.

One of the more successful services offered to scientists is the *Communicating Ocean Science* (COS) university course and the *Communicating Ocean Science to Informal Audiences* (COSIA) program. (See link in the References section at the end of this document). These courses engage scientists in learning how contemporary learning theory combines with rigorously effective teaching strategies to bring their data, research or other work to a broader audience. Developed at University of California, Berkeley's Lawrence Hall of Science as part of COSEE CA and now used by nearly 30 Centers and universities nationwide, these courses are enabling beginning and seasoned scientists to more easily and effectively educate others. Internal and external evaluations of COS and COSIA have amply demonstrated their impact on the ability of scientists to communicate to non-scientific audiences. The Center for Research, Evaluation and Assessment (project evaluators at UC, Berkeley) stated that the "COSIA course has been a successful project that has made significant impacts on target audiences...with direct tangible benefits…." (Halversen 2010).

COSEE Alaska (AK) conducts a half-day *COS Workshop* at its annual five-day Alaska Marine Science Symposium, a conference for scientists to present ocean sciences research focused on Alaskan marine regions. The *COS Workshop* attracted more than 120 scientists and educators in 2011, highlighting outstanding examples of innovative ocean sciences education/outreach.

Hearing detailed examples of scientists accomplishing broader impacts, along with the opportunity to ask questions, is compelling substantiation. Participating scientists claimed they found the sessions interesting, useful, and are likely to use the skills and lessons learned. For several years COSEE GL conducted a *School for Scientists* at the annual International Association for Great Lakes Research (IAGLR) science conference.

COSEE OLC hosted a one-day workshop, *Addressing Broader Impacts Requirements,* with concurrent sessions for scientists to gain skills, insights, and approaches. Attended by more than 100 scientists, evaluation findings confirmed the value of the workshop for participants—98% requested a repeat of the experience (in planning for June 2011). Every session was ranked as either "extremely useful" or "very useful" by at least two-thirds of participants surveyed.

COSEE MA conducted a cultural competency workshop to enable research scientists to be more effective in working with diverse audiences; 100% found the workshop relevant and said they would be willing to attend future workshops on this topic. Participants gained insights about reaching culturally diverse audiences and commonly felt cultural competency training should be a COSEE priority. Subsequently, the COSEE Network has focused two annual meetings on broadening participation and it has become a priority in the Network's strategic planning.

At a smaller scale, COSEE OLC's Ocean Inquiry Project (OIP) prepared scientists to work with youth and adults during research cruises, in which live data was collected, discussed, and analyzed as part of baseline data collection for Puget Sound. The OIP training helped scientists with pedagogical techniques as well as strategies for working with culturally diverse audiences.

Tools for Use With, and in Support of, Education/Outreach

COSEE has supported and refined the development of numerous tools for scientists to use to design and implement quality education/outreach, to achieve broader impacts goals, or to educate others, particularly non-scientists. The range of tools has included websites, webinars, booklets, guides, and brochures. The diversity of these tools and approaches were indicative of the wide range of ocean scientists' interests, needs, locations, and desired outcomes. The variety of approaches supported the achievement of multiple goals and implementation of innovative ideas, while helping with the evaluation and improvement of existing programs or activities.

One of the most successful tools COSEE has developed, used, and disseminated is the Concept Mapping (CM) Online Software refined and tested by COSEE Ocean Systems (OS). This tool supports scientists by helping them create graphical displays of relationships among ocean concepts. It has been rigorously evaluated for usefulness and effectiveness, with 72% of surveyed scientists in 2009 rating it as "useful" to "very useful." The CM tool, and the model for facilitating scientist-educator interactions, has been disseminated to other Centers and to a wide variety of other organizations and research scientists. More than 1,100 web-based concept maps have been produced and posted on the COSEE OS website for scientists (and educators).

Another set of tools was the dozens of webinars and numerous websites, which brought timely information and skills to a larger online audience. These technological designs combined synchronous and asynchronous classes, courses, conversations, information and more, which enabled the maximum number of interested scientists regardless of their schedules. A signature contribution in this sector is COSEE NOW's webinars and discussion groups dedicated to

helping ocean scientists generate new broader impacts ideas, share strategies for improving broader impacts proposals, and implement and evaluate broader impacts activities. NOW's professional development and support efforts blend virtual-personal interactions and build community, especially among those involved in Ocean Observing Systems (OOS) initiatives.

The *Ocean Literacy Framework* (consisting of both the *Ocean Literacy Principles* and the *Ocean Literacy Scope and Sequence*) is a systems approach to ocean sciences and K-12 learning (see link in the References section at the end of this document). It was a significant collaborative effort between scientists and educators, involving many different agencies and organizations, to make ocean sciences more accessible. The *Ocean Literacy Principles* (OLP) applied state-of-the-art learning theory to ocean sciences, and enabled scientists and educators to develop a deeper understanding of each other's "community of practice" and respect for each other's expertise.

Other COSEE-developed materials explained job critical tasks such as developing education/ outreach or how to modify an ocean research poster for a non-technical audience. These resources disseminated needed information, were easily referenced, and provided clear guidelines. One of the more useful and widely disseminated pieces was the *EPO Education and Public Outreach Guide for Scientists*, a collaborative project of COSEE NE, COSEE MA, and COSEE CA. Another widely distributed product, the instructional guide *Teaching Physical Concepts in Oceanography: An Inquiry Based Approach* was developed by COSEE OS with the extensive collaboration of scientists and educators (see links in the References section).

Collaborations & Productive Partnerships in Furtherance of Education/Outreach Mandates

Each Center has vigorously pursued the collaboration mandate, and made those connections easier, more fruitful, and goal-focused. COSEE has built, studied, and refined a Network of ocean scientists who are connected to educators, K-12 teachers and their students, informal science experts, and graduate students. The COSEE Network is a key structure for ensuring the connections between scientists and collaborative partners in formal and informal education. Network meetings occur annually and concurrent sessions are designed specifically to promulgate successful endeavors and to enhance the potential for cross-COSEE collaborations.

The COSEE Network has organized and supported Network-wide collaborations in the form of "working groups" composed of individuals representing the different Centers. These working groups serve the Network and function as a communication channel between and among the Centers. Scientists were involved in most working groups and were direct beneficiaries of the groups' products and impacts.

The Scientist Engagement Working Group (SEWG) received funding from the American Recovery and Reinvestment Act to develop video case studies of scientists engaged in education/outreach (see details in this Decadal Review package). Featuring scientists from each Center, the video collection provides exemplars of successful education/outreach approaches and will generate new insights. Scientists viewing these videos have direct access to the education/outreach experiences of colleagues across the country.

The Diversity Working Group (DWG) provided scientists with greater understanding of the issues and opportunities of working with diverse populations. This group offered guidance to Centers for increasing underrepresented audiences in ocean sciences, produced an annotated

bibliography of research about equity and diversity, and supported efforts of Centers to engage with SACNAS (Society for the Advancement of Chicanos and Native Americans in Science).

The Governance Working Group (GWG) provided a forum for thinking about the organization of a more effective Network to support scientists in doing education/outreach and the creation of a structure from which to operate.

Cross-Center collaborations and partnerships have emerged as a powerful mechanism to support scientists in building their capacities and enhancing their opportunities for education/outreach endeavors. Centers and ocean scientists have benefitted from the synergies of a Network and the catalytic opportunities derived from cross-Center partnerships. Examples include: 1) COSEE PP and COSEE AK to create and disseminate quality professional development for scientists; 2) COSEE OS Concept Mapping workshops and strategies, used by scientists from many Centers to inform and educate local audiences; 3) COSEE NOW's Ocean Gazing podcasts as a new medium for Network-wide scientists to communicate their research to a broad public audience; and 4) COSEE CA's *Communicating Ocean Sciences* network of scientists and educators at multiple institutions of higher education and informal science institutions.

Channel III: Engaging Scientists with Public Audiences

COSEE was able to engage scientists with public audiences to transform ocean sciences education by: 1) organizing events for non-traditional audiences, 2) conducting scientific research and learning sciences research, 3) facilitating the use of real-time ocean observing systems (OOS) data in formal and informal education settings, 4) creating new distance learning and online resources for ocean sciences education, and 5) institutionalizing ocean sciences education/outreach in universities and formal/informal centers. COSEE's success in engaging scientists in ocean sciences education is due to its ability to find and create opportunities for education/outreach, assist scientists in designing their own education/outreach programs featuring their research, and support scientists to become better communicators of their research to non-scientific audiences. Scientists are able to easily participate in existing COSEE activities such as lectures, workshops, and institutes to discuss their research. Scientists consult with COSEE staff to design broader impacts plans as a requirement for funding proposals. COSEE staff also work extensively with scientists in fine tuning their pedagogy skills and finding ways of presenting science content that is understandable to educators and the public.

Events for Non-Traditional Audiences

Centers have organized and collaborated with formal and informal institutions on professional development or public events partnering scientists with tribal leaders and community members, volunteers, naturalists, under-represented students in the sciences, informal educators, and community college faculty. These events go beyond the traditional professional development model of scientists and formal educators. Centers have tailored these events to the needs of different communities. Centers have also been critical in supporting scientists in presenting their research and its larger policy implications to non-scientific audiences to increase public awareness of ocean sciences and demonstrate the larger societal benefits of their research. These events presented the latest ocean sciences research in a way that is accessible to audiences without a prior scientific background. In turn, these audiences are able to take the science content

learned and to teach it to others through presentations to the public at informal science centers or in the field and the demonstration of hands-on activities.

COSEE AK sponsored Ocean Science Fairs for Coastal Communities through the University of Alaska's Center of Cross-Cultural Studies in which teachers, students, and community members investigated scientific and culturally relevant questions focusing on ocean sciences and climate change. Ocean scientists and Alaska Native elders judged the local projects on scientific rigor and cultural relevance, with winning projects entered into the Alaska State Science and Engineering Fair in Anchorage and featured in the annual Alaska Marine Science Symposium.

COSEE Coastal Trends (CT) created a Scientist-Educator Partnerships program where ocean science researchers, grade 7-12 teachers, graduate students, and undergraduate students from Hampton University (a historically black college/university), collaborated for six weeks to conduct ocean sciences research and produce website content.

COSEE OLC, COSEE PP, and COSEE West held professional development events for community naturalists, volunteers, and informal educators at aquaria and other informal education settings that reach out to diverse community groups. These non-traditional educators not only updated their knowledge but also were able to incorporate the latest from ocean sciences in hands-on activities and public exhibits. COSEE PP hosted weeklong workshops where research scientists presented to community college science faculty and assisted them with developing curricula reflecting the most current research.

COSEE West hosted major events for teachers, students, and the public: an air quality-climate change conference for 8,500 high school students and an ocean sciences-climate change conference for 1,000 middle and high school students from Title 1 schools.

While these events allowed research scientists to deliver current scientific research to educators, it also allowed educators to model pedagogical approaches or discuss how they would translate science content for their diverse, non-scientific audiences. The learning has been reciprocal.

Conducting Science Research and Learning Sciences Research

Centers have collaborated with educators and students on scientific research and learning sciences research, utilizing the expertise of COSEE PIs and their colleagues to promote learning and greater dissemination of knowledge. Having educators and students involved in conducting their own research encourages them to become more ocean literate and interested in the ocean sciences and ocean sciences careers. Educators also share this knowledge with their students through lesson plans and hands-on activities. Scientists who have worked with educators and students on science or learning sciences research projects learned more about pedagogy in formal and informal settings and gained insights into the process of learning science.

COSEE Central Gulf of Mexico (CGOM) sponsored a *Sea Scholars Program* on U.S. Navy survey ships for teachers to work with ocean science researchers. COSEE OLC has a *Sound Citizen Science Apprenticeship Program* for middle and high school students to work with University of Washington scientists on water quality studies and to design research projects in their home communities. They have also created opportunities for learning scientists, ocean scientists, and high school teachers to develop place-based environmental curricula and action

plans. Activities targeted high school students under-represented in the sciences and focused on Puget Sound health. COSEE PP developed an internship program for freshmen and sophomore community college students to conduct research with ocean scientists in marine laboratories in Oregon, Washington, and Hawaii. COSEE West has a marine biology quarter every two years for upper level undergraduate students to conduct their own original field research projects in Moorea French Polynesia for one quarter, presenting their results at a student symposium.

Use of Real-Time Data

COSEE has close ties to the Ocean Observing Systems (OOS) research community and has facilitated the use of OOS data (real-time and near real-time) by educators and students. Collaborations between scientists and educators have helped scientists understand what educators needed to incorporate OOS content and data in K-12 classrooms and informal science centers. They have helped educators gain the content knowledge necessary to comfortably implement existing lesson plans and data and to eventually develop their own lesson plans and data. Centers supported educators by creating lesson plans and hands-on activities that have been field tested, as well as by having experienced educators who have taught OOS in their formal and informal settings mentor those less experienced educators.

COSEE MA assisted by COSEE CA conducted a NOAA-funded nationwide study to investigate how K-12 educators and students could use real-time OOS data and educational products in the classroom. COSEE AK worked with the Alaska OOS to create lesson plans (tied to science content standards and *Ocean Literacy Principles*) and videos featuring scientists as part of its *Sound Predictions Project* to educate the public about the Exxon Valdez oil spill on its 20th anniversary. COSEE AK worked with COSEE NOW to produce a two-part podcast, *The Prince's Predictions,* with interviews from scientists and community members on the benefits of an improved OOS in Prince William Sound.

The MATE Center at Monterey Peninsula College, a COSEE NOW partner, started the *Ocean Drifter Project* for community college faculty to develop and share curricula and hands-on activities using real-time data—with funding from NSF and technical assistance by NOAA's Northeast Fishery Science Center. COSEE NOW ocean scientists, learning researchers and educators at Rutgers University developed the *COOLClassroom*, an online suite of lessons using OOS data to teach ocean and spatial literacy concepts. For the past three years, COSEE West has conducted a weeklong summer workshop on OOS to support educators on implementing OOS lessons and hands-on activities in their classrooms as well as developing their own.

Distance Learning, Blended Learning, and Online Resources

Centers viewed distance learning, blended learning (a mix of in-person and online learning) and online resources as valuable methods of information dissemination and engagement that greatly expanded the reach of Centers beyond traditional in-person activities. Some Centers also combined in-person and online learning environments as a means of continuing contact after in-person events.

COSEE CGOM has used distance learning for its summer scientist-educator institutes as a way of maintaining contact between scientists and educators during the academic year via video clips, audio, interactive chat rooms, and presentations. COSEE CT had online educational modules developed by scientists and educators to disseminate science content. COSEE NOW has

developed 60 podcasts for the public (available through iTunes and Facebook) in which ocean scientists tell stories about their research and the broader societal impacts of science. COSEE NOW also conducted 24 webinars (in series of three or four webinars each) for science researchers and educators. In a similar vein, COSEE GL produced online scientist vignettes in which scientists discussed the benefits of broader impacts activities for scientists and educators through their participation in COSEE.

COSEE GL and COSEE West have conducted 13 online workshops on ocean sciences topics ranging from coral reef ecology, harmful algal blooms, and climate change. COSEE NOW recently launched a third revision of its social networking website to continue building its scientist-educator member community. COSEE OLC created a set of web tools to support an online learning community where visitors can post comments, blog, and share resources.

Institutionalization of Ocean Sciences Education/Outreach

Perhaps the most important aspect of engaging more ocean scientists in broader impacts has been the institutionalization of education/outreach in universities, research centers, informal science centers and other settings where scientists work. COSEE CA, COSEE West with other Centers and many ocean sciences education organizations developed the *Ocean Literacy Principles and Fundamental Concepts* (OLP) and the *Ocean Literacy Scope and Sequence* for grades K-12. These identify core concepts of ocean sciences for all and address how this content could be taught at various grade levels. NOAA and NSF now require that grant proposals for ocean sciences education projects use the OLP. This project has also served as a model for the development of the *Climate Literacy Principles, Geology Literacy Principles, Nanotechnology Literacy Principles, Earth Science Literacy Principles*, and *Atmospheric Science Literacy Principles*. COSEE CA supported COSEE GL, supported by COSEE CA, adapting the OLP to create the *Great Lakes Learning Principles* for the eight Great Lakes states.

COSEE CA served as the lead in developing the *Ocean Science Curriculum Sequences* for grades 3-5 and 6-8 funded by NOAA Environmental Literacy Grants. COSEE CA and COSEE NOW have been working closely together to further develop the *Ocean Science Curriculum Sequences*. COSEE scientists and educators have developed lessons and activities that incorporated the OLP and introduced them to scientists, educators, students, and the public at many COSEE events. COSEE SE, COSEE OCEAN and other Centers plan to implement these at various grade levels.

COSEE CA scientists and educators developed the COS and COSIA programs that have been implemented in their original form and adapted by several Centers. COS is a university level course taught by ocean sciences faculty that trains young scientists on how to introduce ocean sciences to K-8 students in the classroom. Nearly 30 universities across the U.S. have COS graduate level courses which are a regular part of the curriculum. COSIA trains scientists on how to introduce the ocean sciences to the public in aquaria and informal science centers. COSEE CA developed partnerships with four other Centers (CT, PP, West, NOW) to implement COSIA in different settings, each with a university partner and an informal science center partner. COSEE CA modified COSIA in Hawaii to incorporate traditional Hawaiian knowledge (*POLYPPS*). COSEE OLC has ocean scientists at the University of Washington that have their graduate students participate in education/outreach through a variety of programs including COSIA, GK-12, *Sound Citizen, Sound Citizen Apprenticeship Program*, and *My Place in Puget Sound*.

COSEE PP implements COSIA for its volunteers and as part of a certification process for educators at aquaria and zoos.

COSEE CA created a MARE Center at the Birch Aquarium, Scripps Institute of Oceanography. MARE is a marine education program designed for informal settings based on the whole school immersion model developed at the University of California Berkeley and Lawrence Hall of Science. COSEE NOW with Liberty Science Center created the Delta Lab, a teaching lab dedicated to OOS data and gliders. COSEE PIs that have had a long-term involvement in COSEE are also beginning to be recognized for their education/outreach efforts by being awarded tenure-track positions and tenure at major universities. For example, Janice McDonnell of COSEE NOW at Rutgers University recently received tenure in recognitions of her contributions to Rutgers and ocean sciences education and to ensure that her contributions continue.

Lastly, Centers have combined other sources of funding and used their COSEE resources to attract additional funding to enhance and continue COSEE programs. These sources of funding included Sea Grant, NOAA, NSF divisions other than OCE, other government agencies and private funding. As a result, Centers have expanded their programs beyond the original scope of their COSEE proposals, consistent with the understanding of COSEE as a catalytic program to transform scientist engagement in ocean sciences education.

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